

# **ULTRA-LIGHTWEIGHT, LOW SCATTER, LARGE MIRROR TECHNOLOGY**

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Department of Defense  
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**BOR**

# **BOR OPTICS FABRICATION FACILITY**

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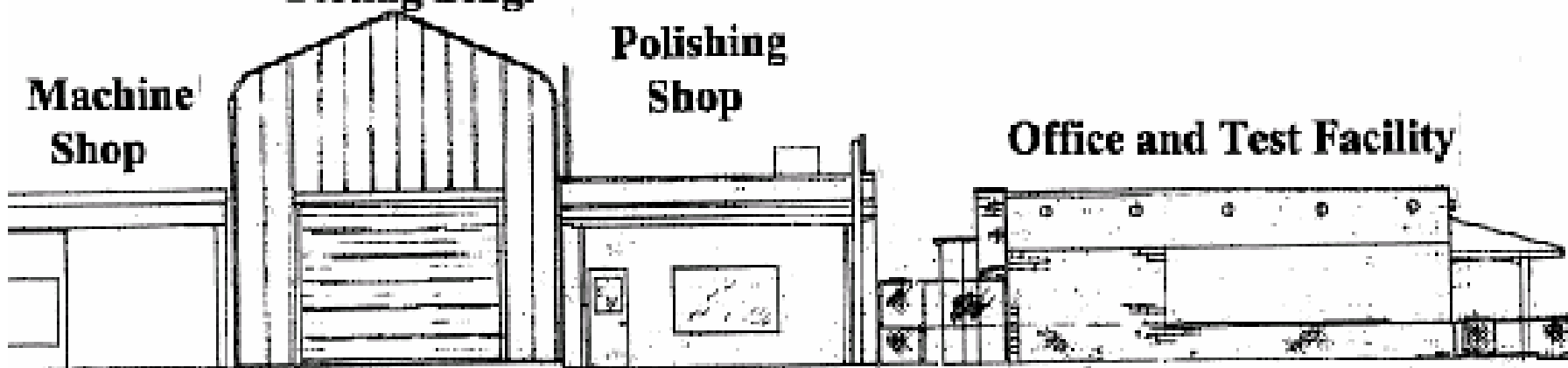
**Microroughness Test and  
White Room Assembly Bldg.  
(Behind Machine Shop)**

**Large Polish and  
Testing Bldg.**

**Machine  
Shop**

**Polishing  
Shop**

**Office and Test Facility**



**Panamint Street**

**5 building complex, June  
2005, 10,000 Sq. Ft.**

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# **HALF-METER DIAMETER AO MIRROR**

**22" diameter adaptive optic mirror, tilt and AO combined.**

**weight 15 lbs (same diameter light weight Zerodur would be 150 lbs.)**

**faceplate 3 mm thick, influence function ~30 cm, graphite filled (76%) cyanate ester, as is mount.**

**good optical figure but sensitive to mount technique. Can superpolish.**

**piezo actuator throw 9  $\mu\text{m}$  for pp voltage 60 V, response ~0.5 kHz.**

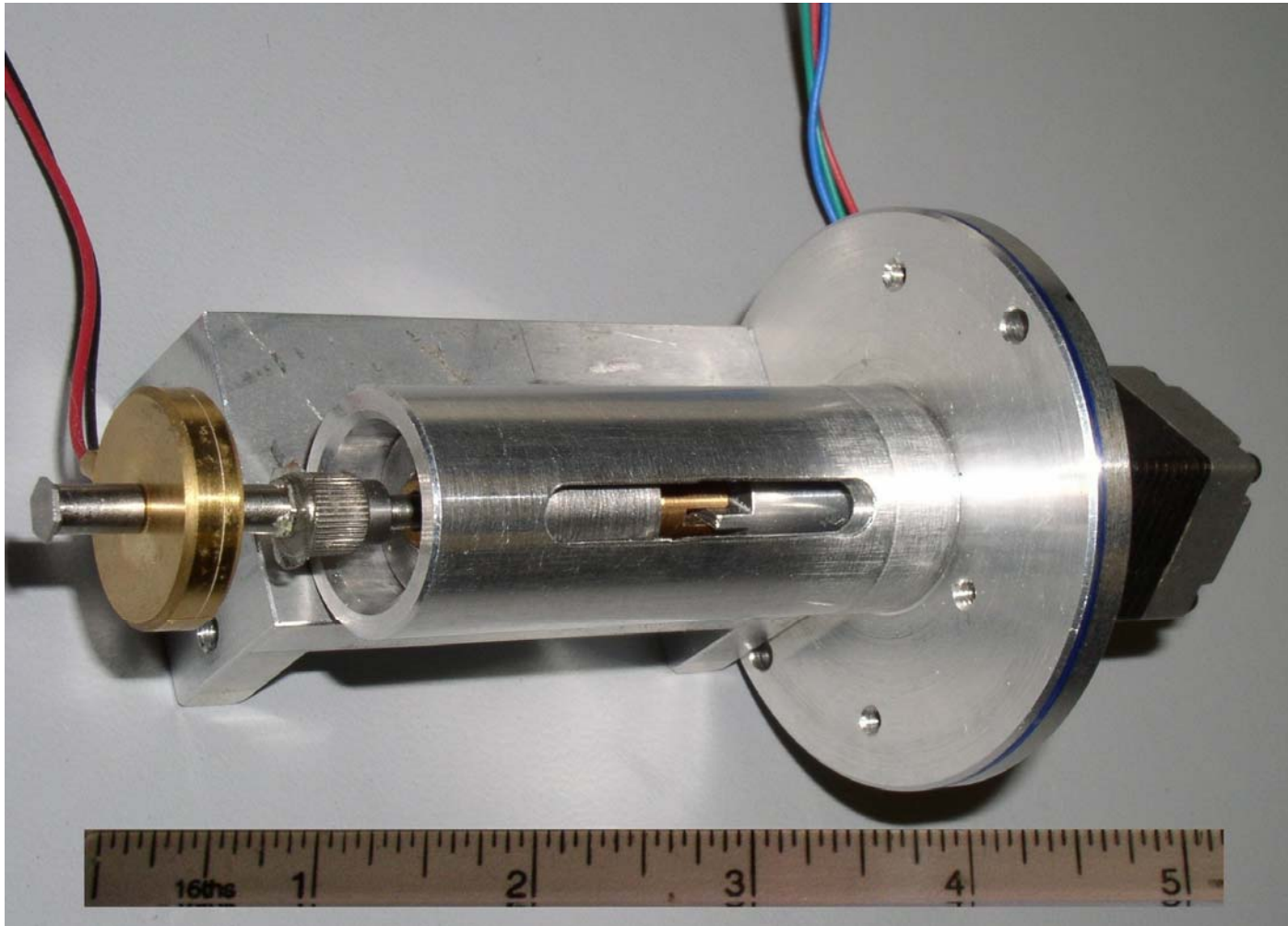
**piezo integral with differential screw actuator, avg. dev. ~0.1  $\mu\text{m}$ , throw > 300  $\mu\text{m}$ .**



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# **BOR ACTUATOR**

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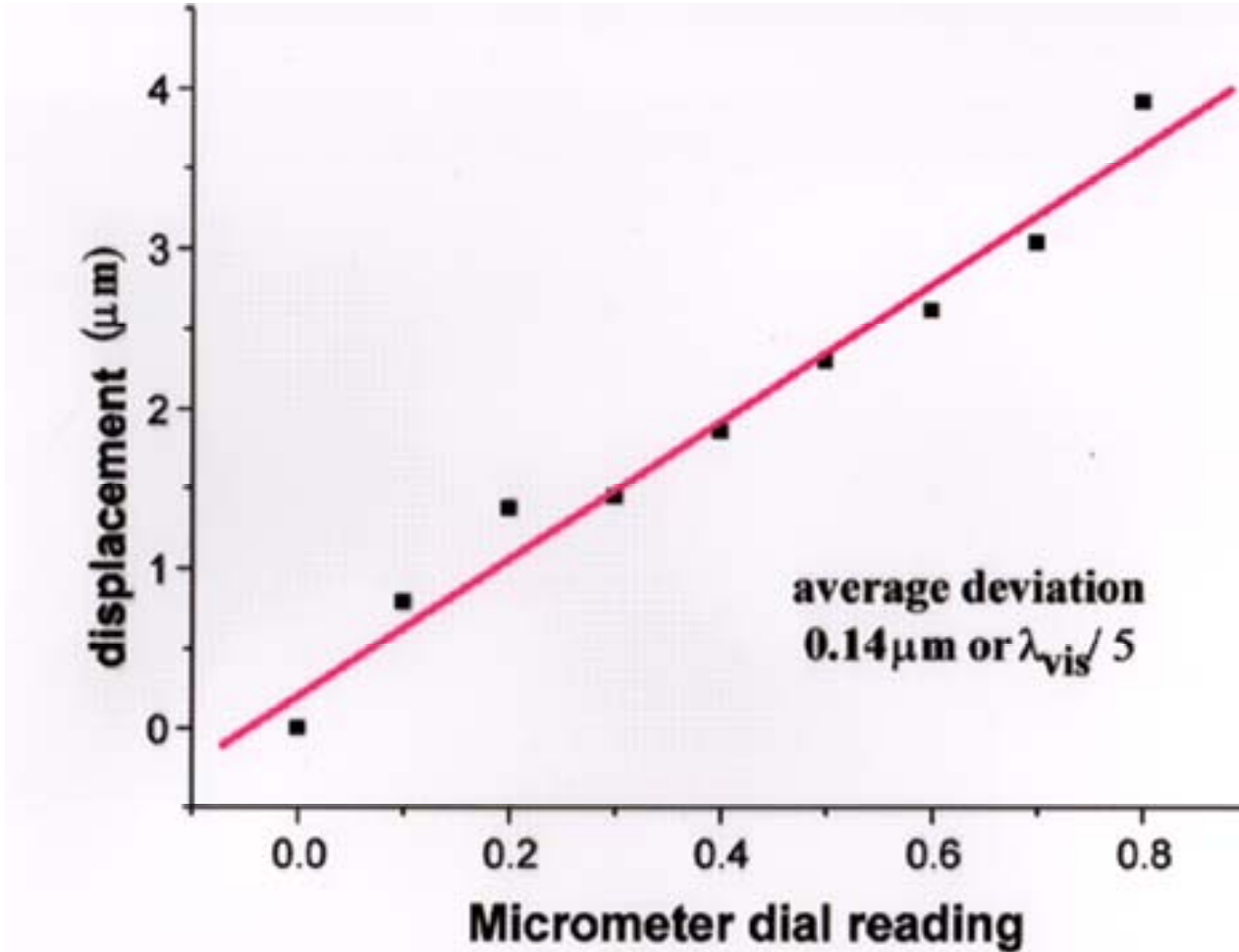
# **BOR Actuator Design**

- 1. Designed for atmospheric correction, tip/tilt and figure maintenance, wt. 8 oz.**
- 2. Piezo-electric low voltage, differential screw 1 cm throw, remote controlled stepper.**
- 3. Stepper (error 5% of step) and screw combined uncertainty is  $\pm 0.15 \mu\text{m}$  or 0.2 waves HeNe.**
- 4. Piezo hysteresis removable by loading.**

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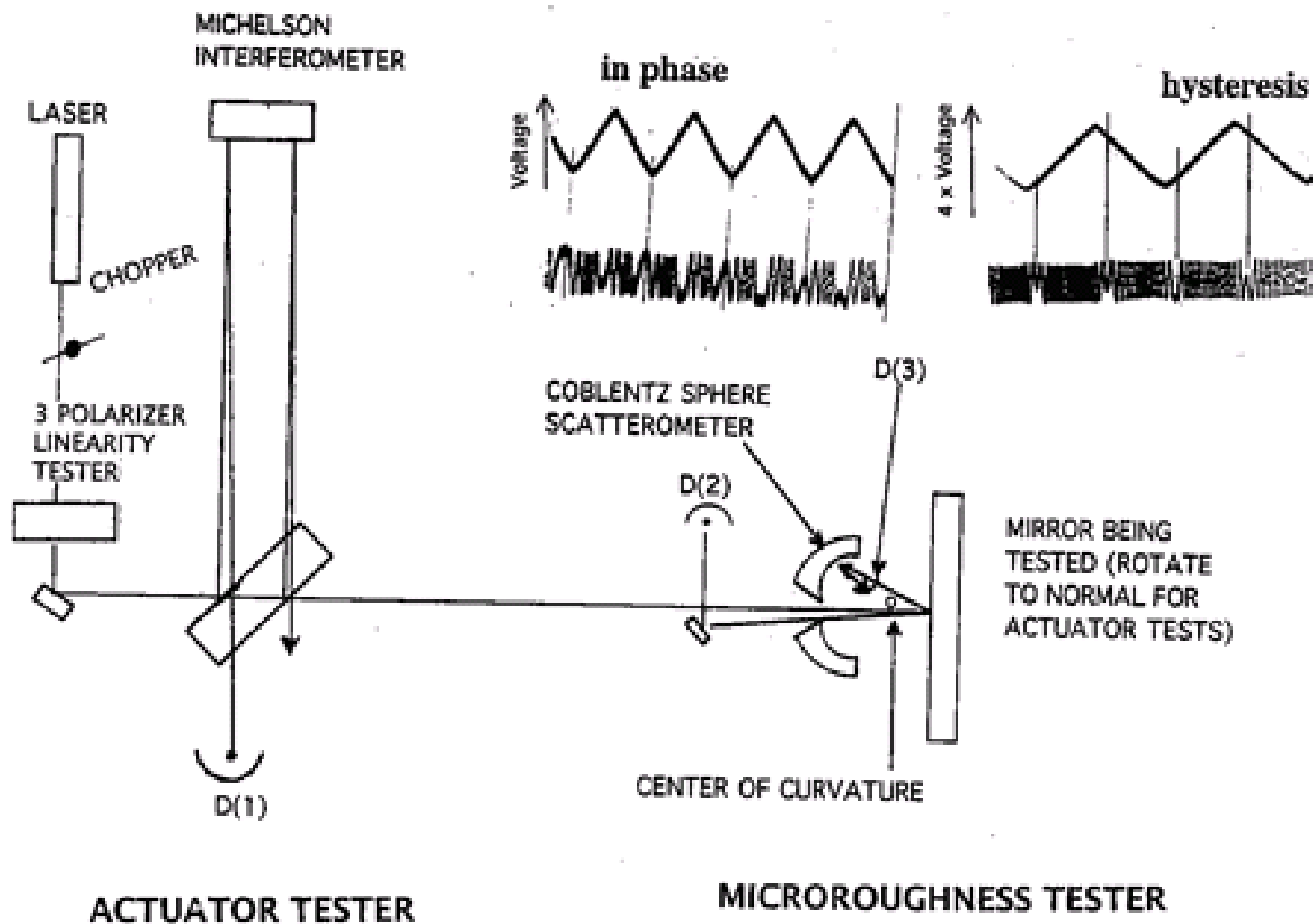
# TRANSLATION OF 20 THREAD/INCH DIFFERENTIAL NUT

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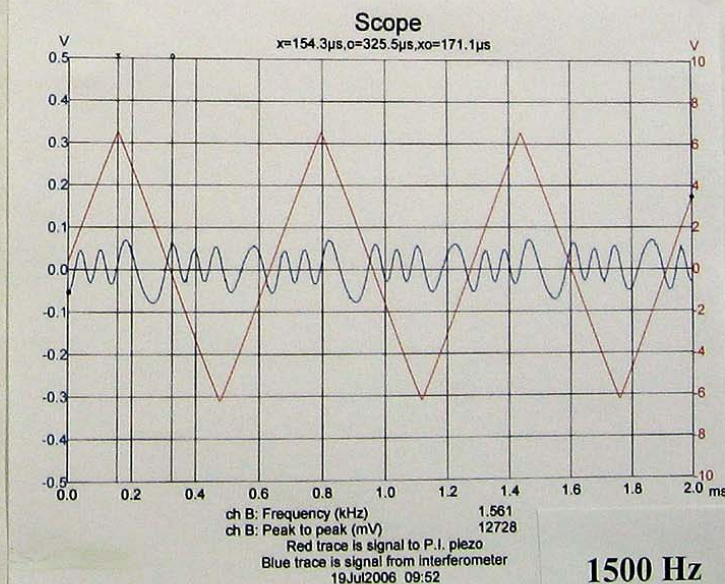
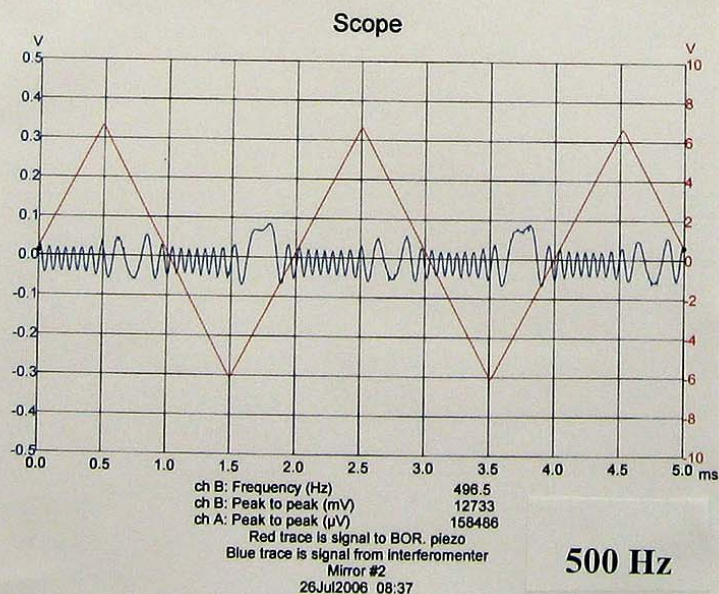
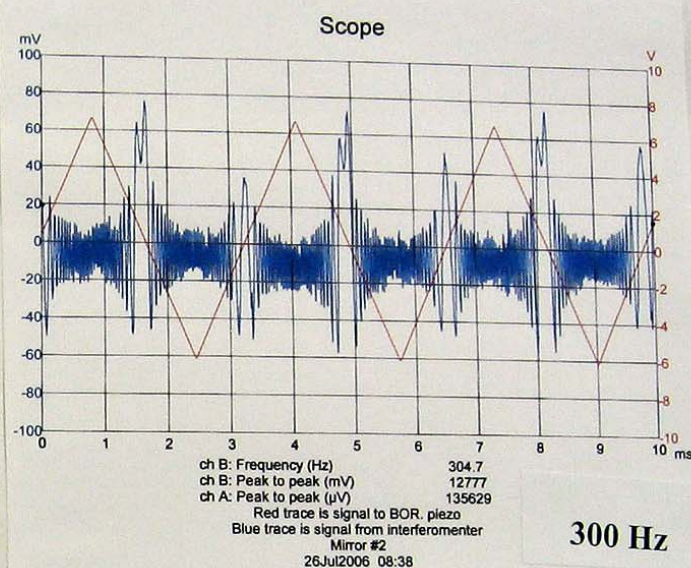
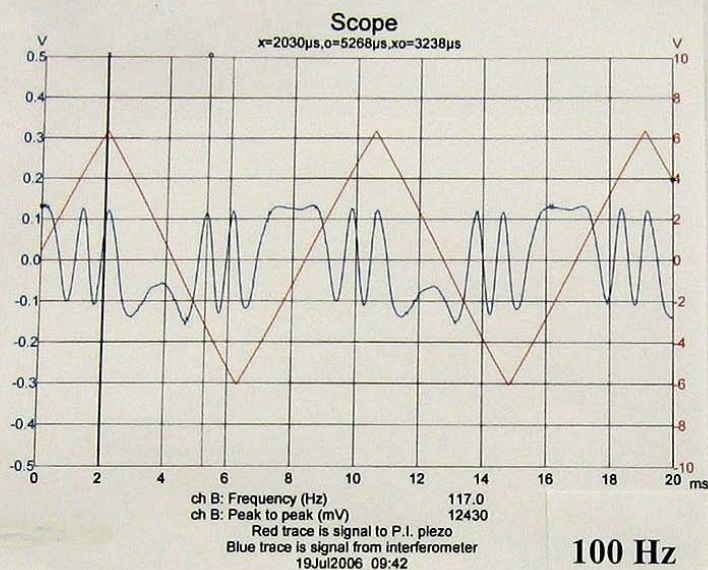


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## AO MIRROR TEST FACILITY

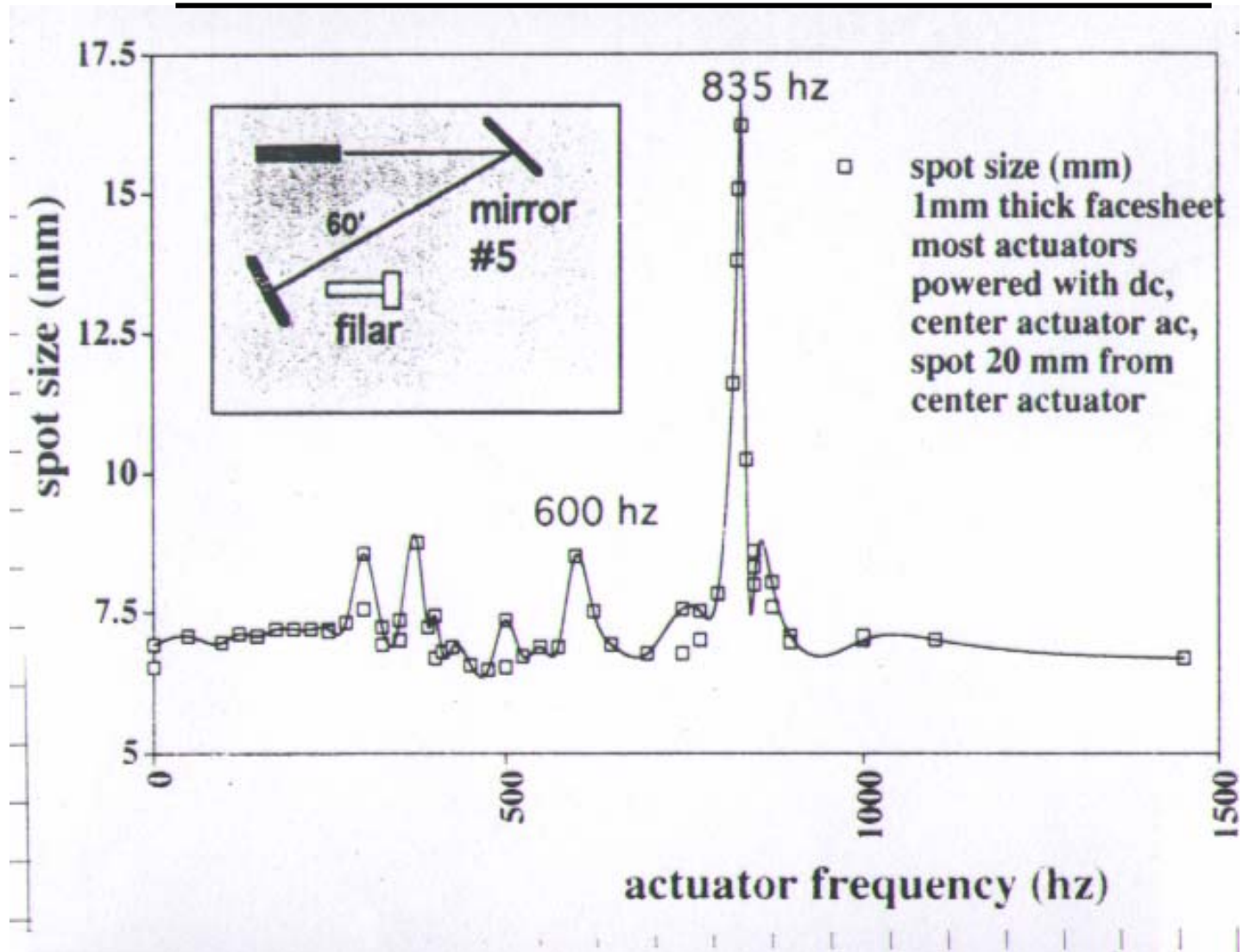


# HYSTERESIS IS NOT VERY DEPENDENT ON FREQUENCY



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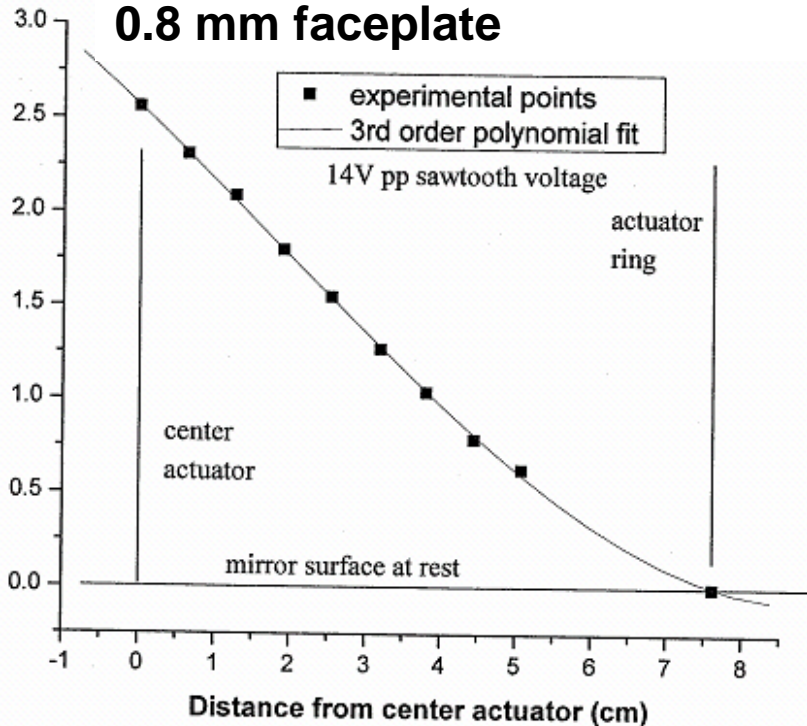
# FACEPLATE RESONANCE CAN BE A PROBLEM



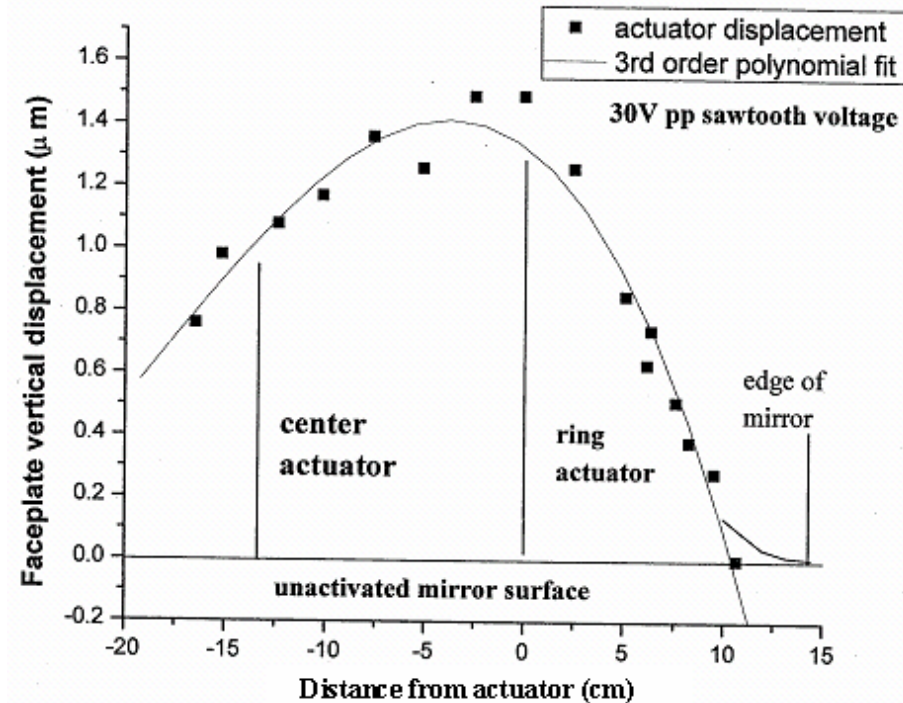
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# Influence Functions for Typical 0.8 mm and 3 mm Thickness Faceplates

12-inch diam composite mirror,  
0.8 mm faceplate



22-inch diam composite mirror,  
faceplate 3 mm thick

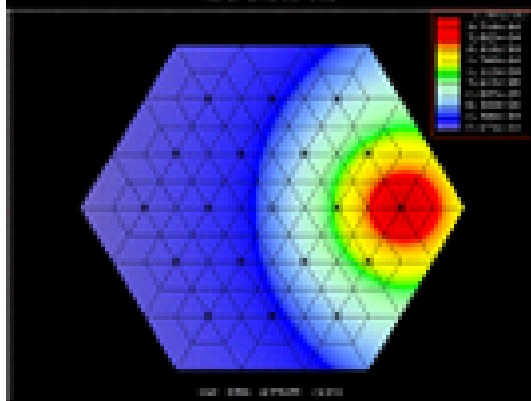
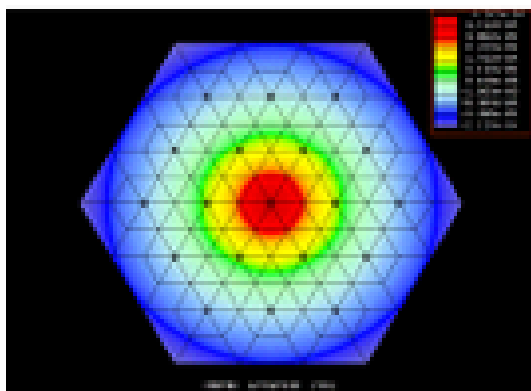


Flexibility  $\sim 1 / t^3$

# Influence Functions for Different Actuators across the Faceplate of a Hexagonal Adaptive Optic Mirror

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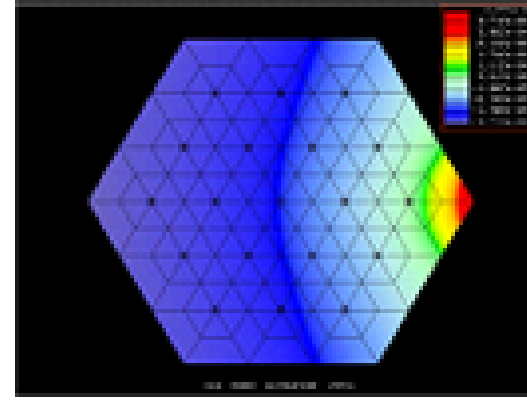
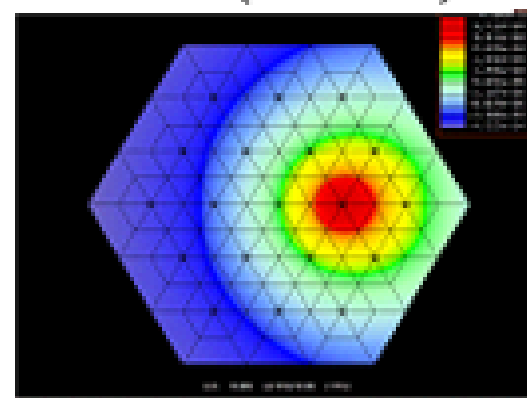
CENTER (70 VOLTS)



2<sup>ND</sup> RING (122 VOLTS)

MAX 14.6  $\lambda$   
MIN -5.9  $\lambda$   
INT 2.6  $\lambda$   
RANGE 20.5  $\lambda$

1ST RING (74 VOLTS)

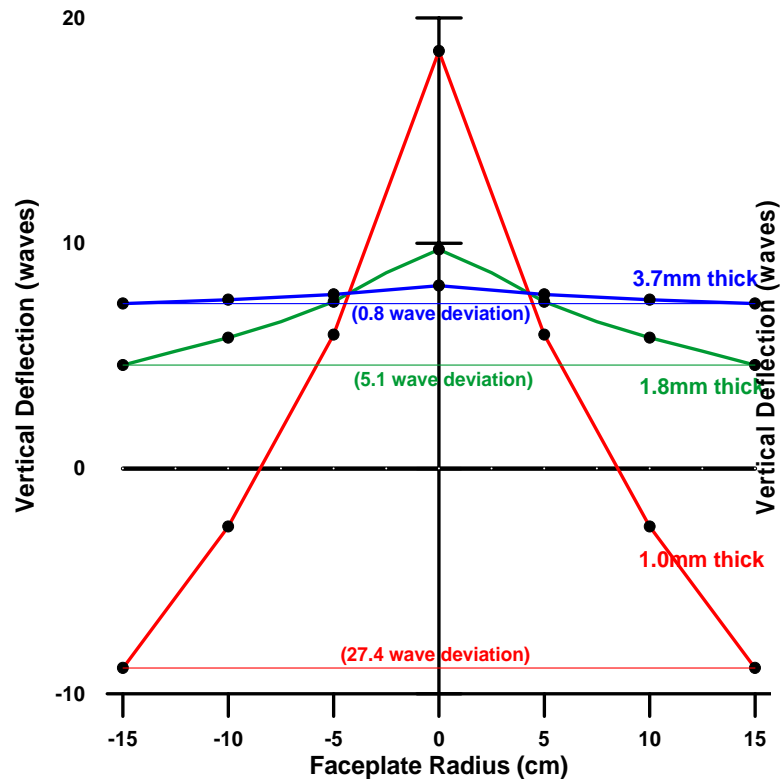


3<sup>RD</sup> RING (47 VOLTS)

# INFLUENCE FUNCTIONS FOR CENTER AND FIRST RING ACTUATORS

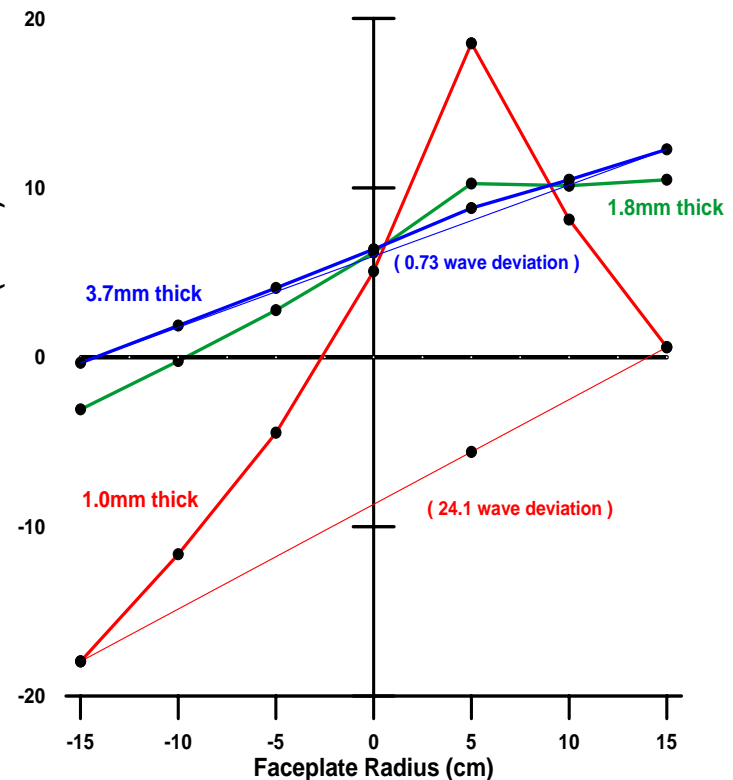
## CENTER INFLUENCE FUNCTION MAPS

8 & 24 LAYER CFRP ( fiber dia. 0.0025" & 0.005" )  
 37 ACTUATOR HEX-ARRAY (CENTER + 3 RINGS)  
 5cm ACTUATOR SPACING, 70 Volt excitation.

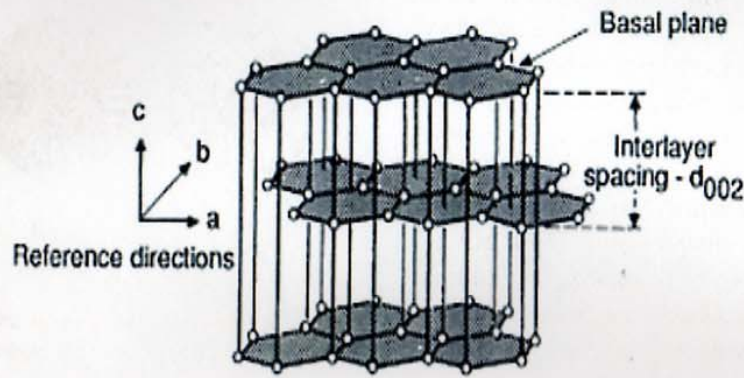


## 1st-RING INFLUENCE FUNCTION MAPS

8 & 24 LAYER CFRP ( fiber dia. 0.0025" & 0.005" )  
 37 ACTUATOR HEX-ARRAY (CENTER + 3 RINGS)  
 5cm ACTUATOR SPACING, 74 Volt excitation.



# Graphite Crystal Lattice



Crystalline form of graphite. In the basal plane the bond strength is 75 times that normal to the plane, so graphite fractures easily in layers parallel to the basal plane.

The long axis of graphite fibers is in the basal plane. In it the thermal expansion coefficient is **negative**,  $-1.2 \times 10^{-6} / \text{deg C}$  at 20 deg C. Perpendicular is large & **positive**,  $+25.9 \times 10^{-6} / \text{deg C}$ . The **Poisson Ratio Coupling Effect** then can produce near-zero CTE of the composite **for certain ply orientations.**

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# Prepreg Precision Alignment Facility

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## **Thermatron Autoclave and Environmental Chamber**



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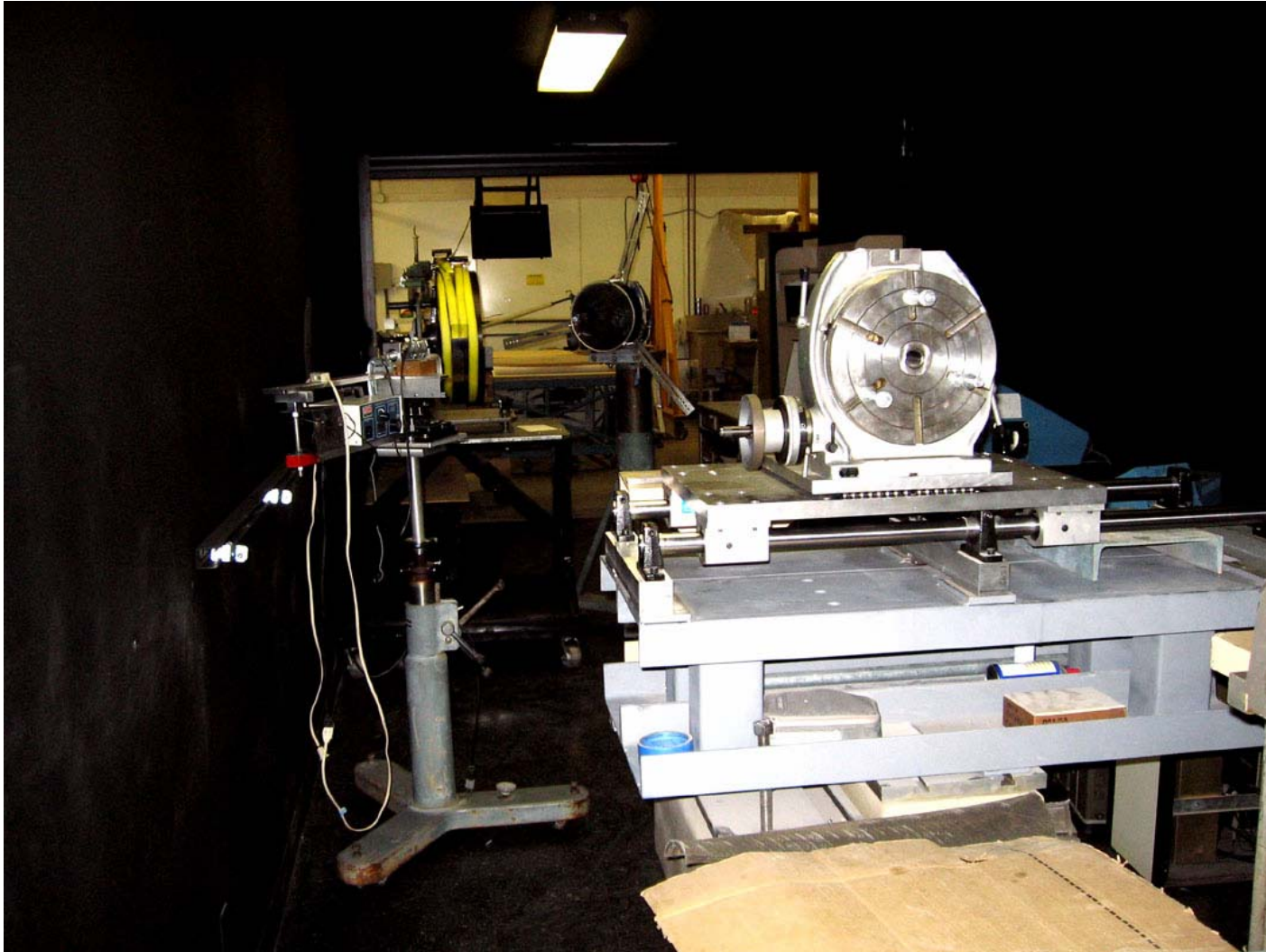
# **POLISHING FRONT SIDE OF ONE-METER MANDREL (TSG)**

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## **50-Foot Optical Tunnel Connects to 1-Meter Polisher**



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# **SUPERPOLISHER, UP TO 1.2 METER MIRRORS, 1/4TH METER SHOWN**

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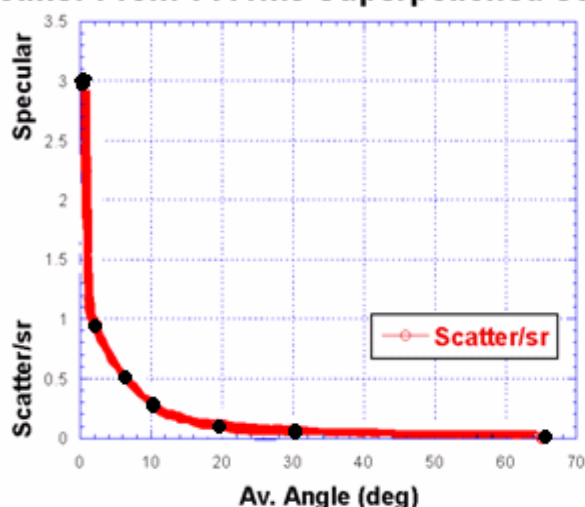
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# SCATTERED LIGHT FROM THIS MANDREL 1/10<sup>TH</sup> THAT OF TYPICAL ASTRONOMICAL MIRROR

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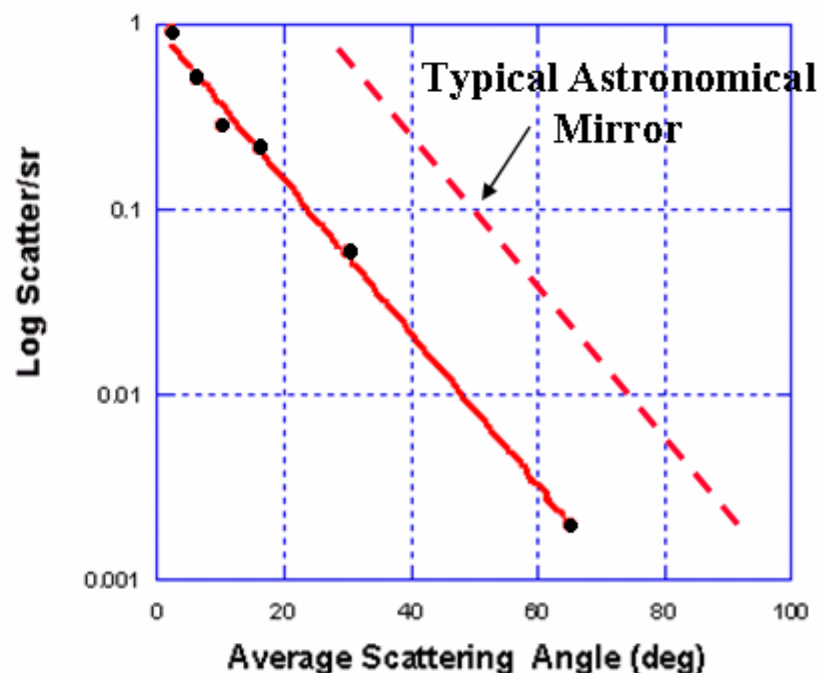
## Specular and Diffuse Reflection

Scatter From 6 Å rms Superpolished Surface



Other Mandrels w/100<sup>th</sup> Astronomical  
Scatter, 2.5 Å rms, made at BOR

Scatter/sr vs. Av. Scattering Angle



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# **AO SCATTER MEASUREMENT AND INTERFEROMETER**

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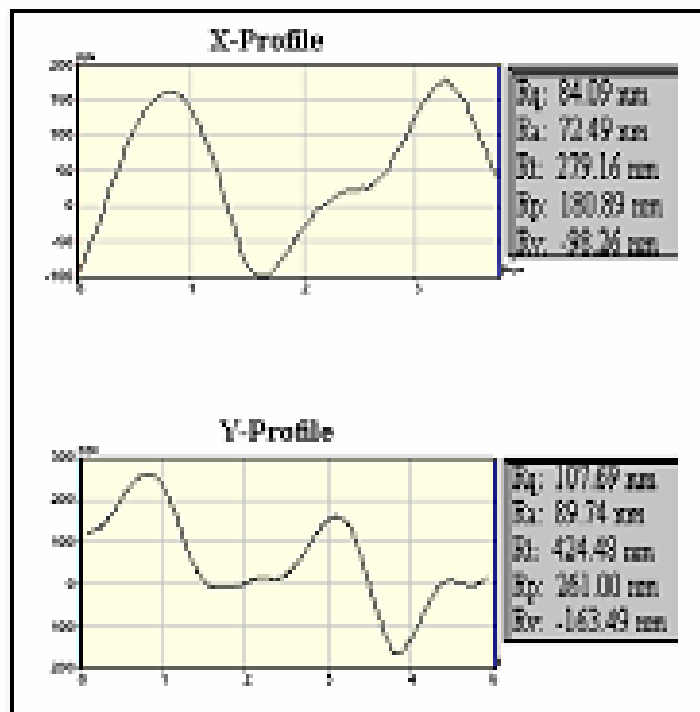
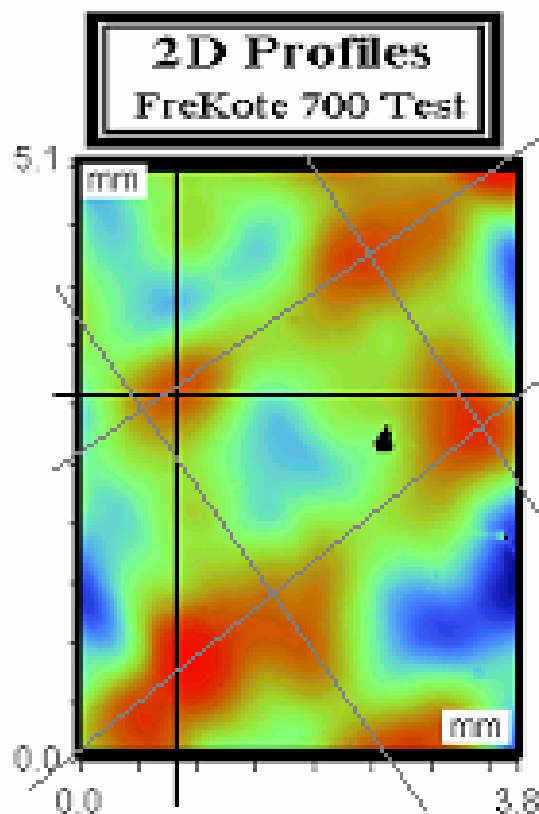
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# Wyko Optical Profilometer



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# PRINT-THROUGH PATTERNS IN A TEST COMPOSITE MIRROR COUPON



NOTES: Print-thru "unit cell"

Mode: PSI Size: 256 X 368 Mag: 1.2 X

BOR opr Danielson

06/16/06

08:18:03



## **CONCLUSIONS**

- 1. Composite 2mm AO mirror faceplates don't fracture, are flexible, expansion  $< 10^{-7}/^{\circ}\text{C}$ , light weight, replaces glass.**
- 2. Meter diameter, adaptive optic, composite mirrors are now being developed at Bennett Optical Research.**
- 3. Low voltage,  $\frac{1}{2}$  msec response actuators with cm throw, remote operation and weighing ~210 g (8 oz.) are now made.**
- 4. Mounting 2 mm thick composite faceplates on tilt corrected actuators rather than on mirror housing can make all actuator influence functions symmetric & equivalent.**